FRIB

FRIB Project Overview for Workforce and Talent Development Committee Michigan House of Representatives

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6 June 2017

MICHIGAN STATE UNIVERSITY

U.S. DEPARTMENT OF ENERGY | Office of Science

The material is based upon work supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661, the State of Michigan and Michigan State University. Michigan State University designs and establishes FRIB as a DOE Office of Science National User Facility in support of the mission of the Office of Nuclear Physics.

Nuclear Science at MSU has a Long and Proud History: Three Major Reinventions

- 1956 MSU hires first accelerator expert
- 1961 NSF approves sector focused K50 cyclotron
- 1965 Research with K50: single turn extration
- 1978 NSAC recommends national user facility at MSU
- 1982 Research with stable beams from K500
- 1989 Research with stable beams from K1200
- 2001 Research with fast rare isotope beams from CCF
- 2002 Infrastructure for SRF linac R&D
- 2005 Research with trapped rare isotope beams
- 2008 DOE selects MSU to establish FRIB
- FY2021 Managing to early completion
- 2022 FRIB completion

Protons
- NSF approves superconducting cyclotron magnet prototype
- 1977 NSF approves K500 cyclotron

Heavy Ions
- Research with fast rare isotope beams from A1200
- 1996 NSF approves coupled cyclotron facility (CCF)

Rare Isotopes
- MSU funds ReA3 reaccelerator project
- FY2017-21 Final NSF 5-year Cooperative Agreement

FRIB

#1 ranked nuclear physics graduate program

MSU awards 10% of nuclear physics PhDs earned annually

- Three disruptive innovations required to survive: Leverage assets to create larger assets. We have to evolve or close the Laboratory

Facility for Rare Isotope Beams

- FRIB will be a $730 million scientific user facility funded by the Department of Energy Office of Science (DOE-SC), Michigan State University, and the State of Michigan
- FRIB Project completion date is June 2022, managing to an early completion in fiscal year 2021
- FRIB will serve as a DOE-SC scientific user facility for world-class rare isotope research supporting the mission of the Office of Nuclear Physics in DOE-SC

FRIB will enable scientists to make discoveries about the properties of these rare isotopes in order to better understand the physics of nuclei, nuclear astrophysics, fundamental interactions, and applications for society

FRIB Design

FRIB Civil Construction Substantially Complete – Now Installing Accelerator

FRIB construction site June 2017

Web cameras at www.frib.msu.edu

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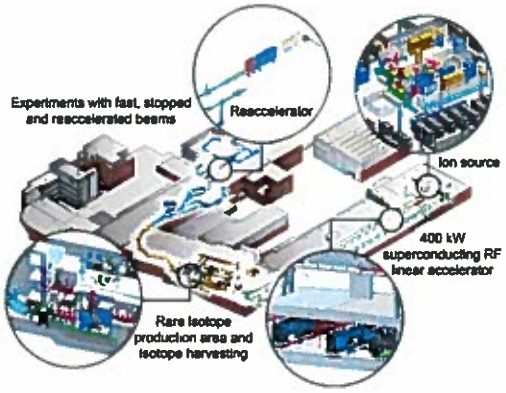
Facility for Rare Isotope Beams

A Future DOE-SC Scientific User Facility for Nuclear Physics

- Supporting the mission of the Office of Nuclear Physics in the U.S. Department of Energy Office of Science
- Serving over 1,400 scientists
- Key feature is 400 kW beam power for all ions ($5x10^{13}$ $^{238}U/s$)
- Separation of isotopes in-flight
  - Fast development time for any isotope
  - Suited for all elements and short half-lives
  - Fast, stopped, and reaccelerated beams



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FRIB Science Is Aligned with National Priorities

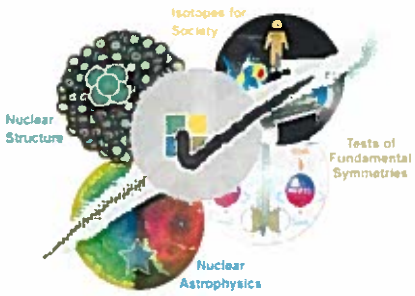
Articulated by Nuclear Science Advisory Committee's *Long Range Plan for Nuclear Science* (2015), National Research Council Decadal Survey of Nuclear Physics (2012), National Research Council *Rare Isotope Science Assessment Committee* Report (2006)

Properties of atomic nuclei
- Develop a predictive model of nuclei and their interactions
- Many-body quantum problem: intellectual overlap to mesoscopic science, quantum dots, atomic clusters, etc.

Astrophysics: What happens inside stars?
- Origin of the elements in the cosmos
- Explosive environments: novae, supernovae, X-ray bursts ...
- Properties of neutron stars

Tests of laws of nature
- Effects of symmetry violations are amplified in certain nuclei

Societal applications and benefits
- Medicine, energy, material sciences, national security

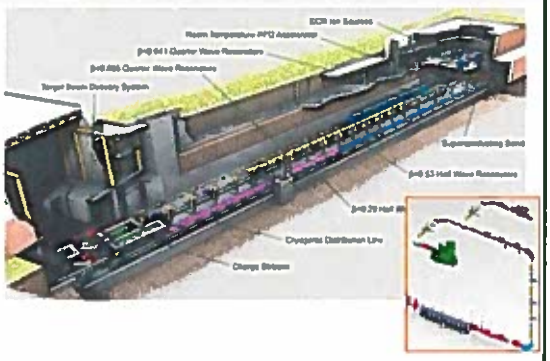


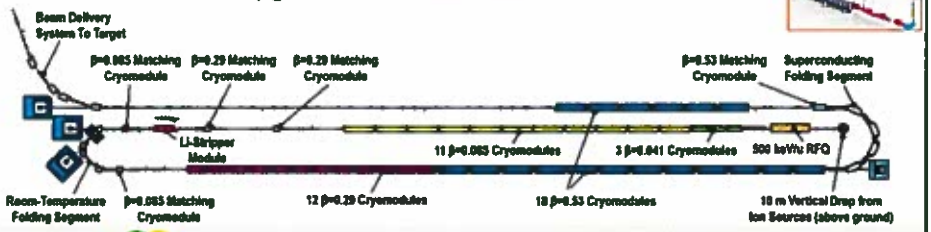
FRIB's History: Persistence and Leadership Pay Off

- 1999: ISOL Task Force Report – proposes Rare Isotope Accelerator (RIA) concept
- 2003: RIA ranks 3rd in DOE 20-year Science Facility Plan
- 2004: DOE determines mission-need for rare isotope facility (called RIA then)
- 2005: DOE cancels draft of RIA-RFP (request for proposal)
  - **MSU proposes alternative at half the cost of RIA**
- 2006: DOE cancels RIA and pursues a lower cost option
  - **MSU publishes "Blue Book" for isotope science facility at half the cost of RIA**
- 2008: DOE issues a Financial Assistance Funding Opportunity Announcement for FRIB (May 20 – application due date July 21)
- 2008: **DOE selects MSU** following a merit review and evaluation process (Dec. 11)
- 2009: **DOE signs Cooperative Agreement with MSU**
- 2010: DOE approves CD-1 (selection of preferred alternatives) for FRIB
- 2013: DOE approves CD-2/3a (project baseline and start of civil construction)
- 2014: Civil construction begins in March
- 2014: DOE-SC approves CD-3b (start of technical construction) in August
- 2014: Technical construction begins in October
- 2017: Civil construction substantially complete in March
- 2022: Completion in June (CD-4), managing to early completion in FY2021

FRIB Accelerator Systems
Superconducting RF Driver Linac

- Accelerate ion species up to ^{238}U with energies of no less than 200 MeV/u
- Provide beam power up to 400kW
- Energy upgrade to 400 MeV/u for ^{238}U by filling vacant slots with 12 SRF cryomodules
- Provisions for ISOL upgrade





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Working With the Best Around the World

- **ANL**
  - Liquid lithium stripper
  - Beam dynamics verification; β=0.29 HWR design; SRF tuner validation
- **BNL**
  - Plasma window & charge stripper, physics modeling, database
- **FNAL**
  - Diagnostics, SRF processing
- **JLab**
  - Cryoplant; cryodistribution design & prototyping
  - Cavity hydrogen degassing; cryomodule design
- **LANL**
  - Proton ion source for Li test
- **LBNL**
  - ECR coldmass; beam dynamics**
- **ORNL**
  - Diagnostics, controls
- **SLAC**
  - Cryogenics**, SRF multipacting**, physics modeling**
- **RIKEN (Japan)**
  - Helium gas charge stripper
- **TRIUMF (Canada)**
  - Beam dynamics design, physics modeling **
  - SRF, QWR etching*
- **GSI (Germany)**
  - Materials
- **INFN (Italy)**
  - SRF technology
- **KEK (Japan)**
  - SRF technology, SC solenoid prototyping
- **IMP (China)**
  - Magnets
- **Budker Institute, INR Institute (Russia)**
  - Diagnostics
- **Tsinghua Univ. & CAS (China)**
  - RFQ
- **ESS (Sweden)**
  - Accelerator Physics*

* Under discussion or in preparation; ** Completed

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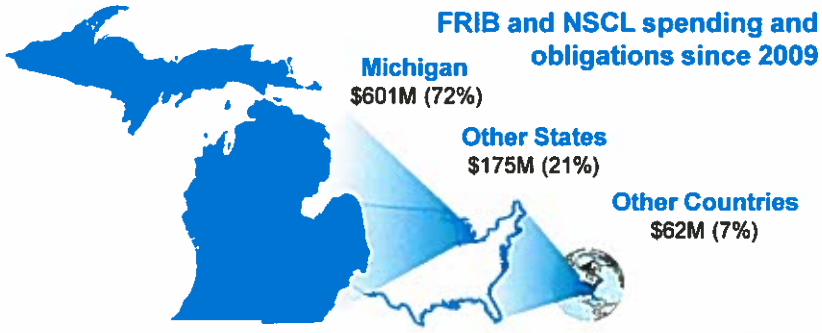
FRIB Project is on Schedule and Budget

- Project started in June 2009
  - Michigan State University selected to design and establish FRIB after rigorous merit-review process
  - Cooperative Agreement signed by DOE and MSU in June 2009
- Conceptual design completed; CD-1 approved in September 2010
- Preliminary technical design, final civil design, and R&D complete
- CD-2/3a approved in August 2013
  - Project baseline and start of civil construction upon further notice from the DOE-SC
- Civil construction began March 3, 2014
- CD-3b review in June 2014
- Technical construction started in October 2014
- Managing to early completion in fiscal year 2021
  - CD-4 (project completion) is 2022
- Cost to DOE - $635.5 million
  - Total project cost of $730M includes $94.5M cost share from MSU
  - Value of MSU contributions above cost share exceeds $212M

Investment in Michigan

- FRIB uses a best-value procurement approach per federal requirements and works to establish long-term relationships with qualified suppliers
- $837M in procurements and labor spent and obligated since 2009, $601M (72%) in Michigan (as of March 2017)



Benefits for Michigan

- The MSU Center for Economic Analysis attributes the following to the FRIB construction activity (FY2009-FY2021) and a 20-year operational phase:
  - FRIB will create up to 1,500 Michigan jobs at the height of the construction phase, and about 1,000 permanent jobs during operations
  - Expected to generate $1.7 billion in accumulated wages & add $4.4 billion to economy
  - Michigan's $94.5 million investment in FRIB is expected to generate $205 million in tax revenues and $831 million in higher gross state product through 2040
  - About 83 percent of construction expenditures go to Michigan businesses and workers
- Transition to knowledge economy
  - Destination for top scientists to conduct research and educate next generation of technology workers
    - » Approximately 1,400 members of FRIB User Group ready to conduct science
      - 164 U.S. institutions and 216 international institutions
      - 113 U.S. colleges and universities, 12 national labs, 51 countries
    - » Programs and tours to actively engage undergraduates and high school students
  - No. 1 ranked nuclear science graduate program, *U.S. News & World Report*
  - MSU educates 10% of nation's nuclear science PhDs annually

Potential for Economic Development

- Technology spinoff and manufacturing
  - Case study: Jefferson National Accelerator Facility (JLab), Newport News, Virginia
    - » $679.1M in economic output and 4,422 jobs annually
    - » $271.1M output and 2,200 jobs in the state
    - » $217.6M and 1,968 jobs remain in metro region
      - From 2010 Economic Impact Analysis
- University Research Corridor (URC)
  - Generated $16.5 billion in economic impact statewide, exceeded $2 billion in annual research expenditures and awarded more than 34,500 degrees in 2016 (urcmich.org)
- Lansing Area Economic Partnership (LEAP) identifying and developing opportunities in mid-Michigan

Basic Research in Rare Isotopes Leads to Applications for Society

- Medical applications
  - Isotopes for medical research
  - Medical imaging and treatment of cancer and tumors
- Energy
  - Reliable calculation of fission and energy generation
  - Allow mechanisms of radiation damage to be studied in detail
  - Sensitive probes for the development of new materials, e.g. lithium-film batteries
- Homeland security and defense
  - Detectors at borders and throughout the country to detect nuclear material and components
  - Nuclear scanning techniques to screen cargo and luggage
  - Nuclear forensic methods to track and trace nuclear material
- Workforce
  - Development of talent for technical, medical, security, and industrial fields

Summary

- FRIB will be a one-of-a-kind science facility designed, built, and operated by Michigan State University in support of the U.S. Department of Energy's Office of Nuclear Physics
- Project on track with civil construction having achieved beneficial occupancy on March 24, 2017
- FRIB is a game changer for nuclear science
  - World's most powerful rare isotope research facility
  - Users are engaged and ready for science
- FRIB will benefit the state and region
  - Job creation
    - » Construction jobs now
  - Knowledge economy
    - » FRIB will attract top scientists and scholars
  - Talent and technology spinoff in the future